SMALL-SCALE MECHANICAL RESPONSE OF CEMENTED CARBIDES: CORRELATION BETWEEN MECHANICAL PROPERTIES AND MICROSTRUCTURE

J.J.Roa, CIEFMA, Technical University of Catalonia-BarcelonaTech, EEBE, Spain
joan.josep.roa@upc.edu
M.Monclús, IMDEA Materials. Getafe, Madrid, Spain
D.A.Sandoval, CIEFMA, Technical University of Catalonia-BarcelonaTech, EEBE, Spain
W.C.Oliver, Nanomechanics, Inc. A KLA-Tencor Company. Oak Ridge, USA
J.M.Molina-Aldareguía, IMDEA Materials. Getafe, Madrid, Spain
L.Llanes, CIEFMA, Technical University of Catalonia-BarcelonaTech, EEBE, Spain

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The unique combination of hardness, toughness and wear resistance exhibited by heterogeneous hard materials (e.g. cemented carbides, PCD composites, PcBN systems and generic hard coating/substrate combinations) has made them preeminent material choices for extremely demanding applications, such as metal cutting/forming tools or mining bits, where improved and consistent performance together with high reliability are required. The remarkable mechanical properties of these materials results from a two-fold effectiveness associated with their intrinsic composite character. On the one hand in terms of composite nature: combination of completely different phases (hard, brittle and soft, ductile constituents) with optimal interface properties. On the other hand as related to composite assemblage: two interpenetrating-phase networks where toughening is optimized through different mechanisms depending on the relatively different chemical nature among them.

In particular, this presentation is focused on WC-Co hardmetals, as reference hard material. Large number of studies has been reported, mainly focused on the mechanical behavior of this composite. On the other hand, information on the small-scale mechanical response of these materials is rather scarce. This is particularly true regarding experimental data and analysis on the influence of phase nature, crystal orientation (anisotropy) and interfacial adhesion strength on hardness, deformation and/or damage mechanisms. It is clear that knowledge of these issues is crucial not only to improve the performance of hardmetals but also to develop ceramic-metal composites beyond WC-Co systems.

A systematic micro- and nanomechanical study of the mechanical response of several microstructurally different WC-Co grades is presented. In doing so, nanoindentation technique is implemented and corresponding deformation/damage mechanisms are also investigated. In general, five different approaches are followed to accomplish the main goal of this research: (1) assessment of intrinsic hardness values and main deformation mechanisms as a function of crystal orientation for the carbide phase at room temperature (RT) and also at high temperature (from RT to 600 ºC), (2) determination of effective hardness and flow stress of the metallic binder through massive nanoindentation and statistical analysis, (3) evaluation of the Hall-Petch parameters for the WC-Co as a function of a microstructural parameter (mean free path) by using the methodology presented above, (4) correlation of the microstructure with the hardness and elastic modulus map by using high indentation speed tests, and (5) study of the stress-strain response by means of ex/in-situ compression of micropillars.

It is found that WC-Co composites are strongly anisotropic in terms of hardness at the small scale (microstructure), being the WC hardness for the basal plane about 20-30% higher than for the prismatic and pyramidal planes. It implies consideration of carbides with different crystal orientations as distinct phases for statistical analysis of massive nanoindentation data. Implementation of such testing/analysis protocol indicates a flow stress for the constrained Co-based binder of about 2.6-3.5 GPa. By plotting of the experimentally data as a function of the binder mean free path results in a Hall-Petch strengthening relationship.

Finally, the compression of micropillars points out that main deformation mechanisms are located in the metallic binder although close to the strong interface exhibited by these materials.